



TREATMENT TECHNOLOGY

Relating the Physical and Chemical Properties of Petroleum Hydrocarbons to Soil and Aquifer Remediation

by Evan K. Nyer and George J. Skladany

I would like to change the style of this column for this issue. Instead of reviewing treatment methods applicable to a specific cleanup, I want to perform a more detailed review of the physical and chemical properties of petroleum hydrocarbons. This review can then be related to different remediation methods. I have tried to provide sufficient data in this article for the reader to use as reference material in future work. Because of the nature of the details involved, I have asked George Skladany to help me summarize and present these properties.

Petroleum hydrocarbons are one of the most frequent sources of ground water contamination. Leaking underground storage tanks at gasoline stations, spills at oil terminals, and leaks in fuel pipelines combine to make these compounds a recurring problem. Gasoline, diesel, and fuel oils are some of the most common petroleum products contaminating soils and ground water. While these products are generally spoken of as single entities, each is actually a complex mixture of many organic chemicals. Each of these specific chemicals has its own properties and behavior when in contact with soils and water. While it is correct to say that an aquifer has been polluted with the general contaminant "gasoline," remediation efforts must address the treatment of the specific organics present.

Physical and Chemical Properties

Chemical Composition

Let us start with simple definitions for gasoline, diesel, and fuel oils (Hawley 1981):

- Gasoline is a mixture of volatile hydrocarbons suitable for use in internal combustion engines. The major chemical components of gasoline are branched chain paraffins (branched chain alkanes), cycloparaffins (cycloalkanes), and aromatics.

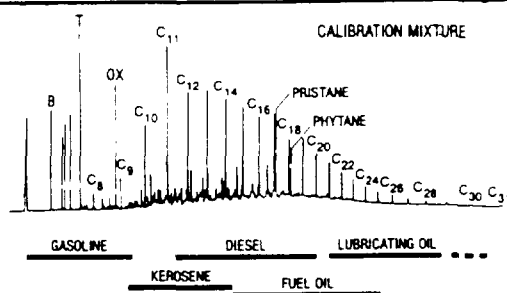


Figure 1. Approximate boiling ranges for individual hydrocarbon products. Benzene (B) has a boiling point of 80.1 C and n-Hentriacotane (C-31) has a boiling point of 302 C (from Senn and Johnson 1985).

TABLE 1
Petroleum Distillation Products

Fraction	Distillation Temperature, °C	Carbon Number
Gas	Below 20	C-1 to C-4
Petroleum Ether	20 to 60	C-5 to C-6
Ligroin (light naphtha)	60 to 100	C-6 and C-7
Natural Gasoline	40 to 205	C-5 to C-10 and cycloalkanes
Kerosene	175 to 325	C-12 to C-18 and aromatics
Gas Oil	Above 275	C-12 and higher
Lubricating Oil	Non-volatile liquids	Probably long chains attached to cyclic compounds
Asphalt or Petroleum Coke	Non-volatile solids	Polycyclic structures

Adapted from Morrison and Boyd 1973

- Diesel is Number 2 fuel oil, composed of unbranched paraffins (straight chain) with boiling point between 110 and 190 F (43 and 89 C).
- Fuel oils are chemical mixtures with boiling points greater than 100 F (38 C). Fuel oils are composed of fractions of petroleum, residuum from refinery operations, crude petroleum, or a mixture of these materials.

Basically, these different petroleum products are composed of progressive "cuts" of a distillation column. Some of the major commercial products are gasoline and different distillation fractions. Figure 1 shows the major petroleum hydrocarbon constituents that appear in a gas chromatograph separated by increasing the boiling point. Gasoline is a mixture of chemicals with boiling points between 40 and 173 C. Gasoline contains relatively small amounts of benzene, toluene, and xylene, which other hand consist primarily of straight chain alkanes. Diesel fuel, therefore, would not be expected to contain large amounts of aromatic compounds (Senn and Johnson 1985).

The source of the crude oil used in a remediation project has an effect on the composition of the product. For example, Table 2 shows the composition of paraffins, cycloparaffins, and aromatics in different types of crude oil. Variability is also seen in the gasoline fraction produced from the crude oil. For example, the gasoline from the Conroe, Texas, crude oil contains 16.19 percent toluene on a volume basis, while the gasoline from Colima, California, contains only 2.22 percent benzene and 7.94 percent toluene on a volume basis (Perry 1984).

Physical Properties

Above-ground or in situ remediation of contaminated soils or waters must consider the physical and chemical properties of the organics present. Cleanup of spills must also consider the combined cleanup of several individual organic compounds. Each of these organic compounds has its own physical and chemical properties.

The Relative Amount of Individual Organic Compounds

Origin of Crude Oil

Oklahoma (Ponca)
Pennsylvania
Texas (Hastings)
California (Santa Fe Springs)
Canada (Turner Valley)
Mexico (Altamira)
Rumania (Bucarest)
Kuwait
Russia (Baku)

Adapted from Perry 1984

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Physical Properties of Gasoline to Soil and on

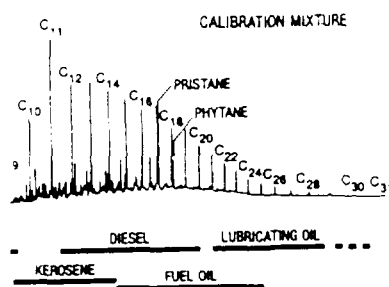
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Physical Properties

Composition

Gasoline is a mixture of volatile hydrocarbons suitable for use in internal combustion engines. The major components of gasoline are branched chain alkanes, cycloparaffins and aromatics.

Gasoline is a mixture of volatile hydrocarbons suitable for use in internal combustion engines. The major components of gasoline are branched chain alkanes, cycloparaffins and aromatics.



Approximate boiling ranges for individual hydrocarbon compounds (B) has a boiling point of 80.1°C and n-Hentri- has a boiling point of 302°C (from Senn and Johnson 1985).

Carbon Number
C-1 to C-4
C-5 to C-6
C-6 and C-7
C-5 to C-10 and cycloalkanes
C-12 to C-18 and aromatics
C-12 and higher
Probably long chains attached to cyclic compounds
Polycyclic structures

- Diesel is Number 2 fuel oil, composed primarily of unbranched paraffins (straight chain alkanes) with a flash point between 110 and 190°F (43 and 88°C).
- Fuel oils are chemical mixtures having flash points greater than 100°F (38°C). Fuel oils can be distilled fractions of petroleum, residuum from refinery operations, crude petroleum, or a mixture of two or more of these materials.

Basically, these different petroleum mixtures represent progressive "cuts" of a distillation column. Table 1 presents some of the major commercial products associated with different distillation fractions. Figure 1 shows some of the major petroleum hydrocarbon constituents as they would appear in a gas chromatograph separating compounds by increasing the boiling point. Gasoline is, in general, a mixture of chemicals with boiling points less than that of decane (those compounds with boiling points between 36 and 173°C). Gasoline contains relatively large concentrations of benzene, toluene, and xylene. Diesel fuels on the other hand consist primarily of higher boiling-point straight chain alkanes. Diesel fuel contaminated soils therefore would not be expected to contain high concentrations of aromatic compounds (Senn and Johnson 1985).

The source of the crude oil used for refining also has an effect on the composition of the final petroleum product. For example, Table 2 shows the volume percent of paraffins, cycloparaffins, and aromatics present in nine types of crude oil. Variability is again observed in the gasoline fraction produced from three crude oils, as shown in Table 3. For example, the gasoline fraction made from Conroe, Texas, crude oil contains 3.27 percent benzene and 16.19 percent toluene on a volume basis. The gasoline fraction made from Colinga, California, crude oil contains only 2.22 percent benzene and 7.94 percent toluene on a volume basis (Perry 1984).

Physical Properties

Above-ground or in situ remediation of hydrocarbon contaminated soils or waters must address the specific organics present. Cleanup of spilled gasoline is actually the combined cleanup of several individual organic chemical compounds. Each of these organics has specific phys-

TABLE 3
Some of the Major Constituents of the Gasoline Fraction (b.p. 36–117°C) in Selected Petroleum

Constituent	Volume (%)		
	Conroe, TX	Colinga, CA	Jennings, LA
Alkanes:			
n-Pentane	0.33	0.44	1.12
n-Hexane	6.44	7.75	9.15
n-Heptane	6.9	5.94	8.42
2-Methylpentane	2.89	2.56	3.47
2,3-Dimethylhexane	0.22	1.3	2.39
Cycloalkanes:			
Cyclopentane	0.96	1.76	0.67
Methylcyclopentane	6.51	10.29	5.01
Cyclohexane	10.4	7.63	7.13
Methylcyclohexane	22	14.55	18.07
Ethylcyclopentane	2.03	4.38	2.34
Trimethylcyclopentane	3.64	8.12	4.18
Aromatics:			
Benzene	3.27	2.22	3.61
Toluene	16.19	7.94	12.02

Adapted from Perry 1984

ical, chemical, and biological properties. First let us summarize the specific compound properties.

Gasoline is a chemically complex petroleum product composed of short branched and straight chain alkanes (paraffins), cycloalkanes, and aromatics. Figure 2 provides several examples of these classes of compounds. The molecular weight, density, solubility, boiling point, and vapor pressure for several compounds in gasoline, diesel, and fuel oil are presented in Table 4.

As shown in Table 4, the number of carbon atoms present in a compound has a major effect on its properties. Alkane chains up to 17 carbons in length are liquids and have densities less than that of water (<1). Alkane chains

TABLE 2
The Relative Amount of Paraffins, Cycloparaffins, and Aromatics in the Gasoline Fraction of Representative Crude Oils

Origin of Crude Oil	Boiling Range (°C)	Volume (%)		
		Paraffins	Cyclo-Paraffins	Aromatics
Oklahoma (Ponca)	55–180	50	40	10
Pennsylvania	40–200	70	22	8
Texas (Hastings)	50–200	27	67	6
California (Santa Fe Springs)	45–150	41	50	9
Canada (Turner Valley)	45–200	51	35	14
Mexico (Altamira)	40–200	49	36	14
Rumania (Bucani)	50–150	56	32	12
Kuwait	40–200	72	20	8
Russia (Baku)	60–200	29	63	8

Adapted from Perry 1984

with 18 or more carbons in length are actually solids at room temperature and are commonly referred to as waxes. Alkane solubility rapidly decreases as the number of carbons present in the compound increases. Pentane, with a chain length of five carbons, has a solubility of 360 ppm at 16 C; hexane (with six carbon atoms) has a solubility of 13 ppm at 20 C; and decane (with 10 carbon atoms) has a solubility of only 0.009 ppm at 20 C.

Vapor pressures also decrease as alkane carbon numbers increase. High vapor pressures indicate that a compound can easily volatilize; low vapor pressures are associated with chemicals that are semivolatile or non-volatile. Methane (1 carbon), ethane (2 carbons), propane (3 carbons), and butane (4 carbons) are usually found as gases. For the liquid alkanes previously discussed, pentane has a vapor pressure of 430mm of Hg at 20 C, hexane of 120mm of Hg at 20 C, and decane of only 2.7mm of Hg at 20 C. Boiling point temperatures for alkanes, however, increase with the number of carbons present.

Cycloalkanes are similar to straight or branched chain alkanes in properties. Their densities are less than one, solubilities and vapor pressure decrease with the carbon number, and boiling point temperatures increase with the carbon number.

The aromatic fraction of petroleum products is perhaps the most important group of chemicals from an environmental point of view. Benzene, toluene, and the xylenes (BTX) each have densities less than 1. Benzene is the most soluble of this class at 1780 ppm at 20 C. Toluene has a solubility of 515 ppm at 20 C. The isomeric xylenes have different solubilities: 175 ppm for ortho and meta-xylene at 20 C and 198 ppm for para-xylene at 25 C. Vapor pressures for these compounds are 76mm of Hg at 20 C for benzene, 22mm of Hg at 20 C for toluene, and approximately 6mm of Hg at 20 C for each of the isomeric xylenes.

Remediation

Now let us look at the effect that different chemical properties have on the remediation of a site. The first thing that we want to know when trying to remediate a

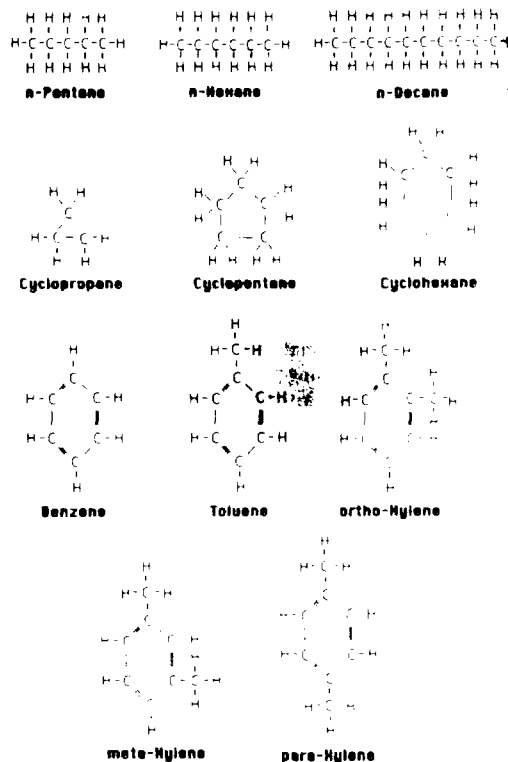


Figure 2. Chemical structures of selected petroleum hydrocarbons.

site is the location of the contaminants. We know that there are three possible phases in which petroleum hydrocarbons can be found. Hydrocarbons are usually released first to the unsaturated soils. Next, the hydrocarbons travel down through the soils and encounter the aquifer. Hydrocarbons in the vadose zone can also volatilize during movement and contribute to the soil gases. Therefore, we can expect to find spilled petroleum hydrocarbons in the soils, the aquifer, and in the soil

gases.

Once petroleum hydrocarbons at the environment they interact with the. Some of the major processes affecting include adsorption, chemical degradation, volatilization, and biodegradation. As constituents of petroleum products and aromatics) are non-polar compounds with limited solubility in water. Naturally occurring compounds, such as humic and fulvic acids, help to dissolve other non-polar compounds in water. Covalent bonding of contaminant groups of humic molecules can also form contaminants. In addition, clays frequently have positively charged surfaces as well as charged contaminants.

A common way to compare migration potentials is to use K_{oc} as a measure of the tendency of an organic compound to be adsorbed by the soil. The higher the K_{oc} value, the lower its mobility. Table 5 gives K_{oc} values for compounds found in gasoline. A discussion of contaminant-soil interactions is beyond the scope of this article. Interested readers can consult texts such as the volume by Dragunov et al.

The problem with remediation is that we do not find all of the chemical compounds in each of the three different phases. The compounds that make up gasoline have low solubility, low volatility, and strong adsorption characteristics will be most prevalent in the aquifer, and the compounds with high solubility will be most prevalent in the soil gases. The natural separation of the chemical compounds is a petroleum product.

Specific chemical properties that are used for remediation as well as for analysis. We will first review remediation

Soils Remediation

There are four major ways to remediate sites contaminated with petroleum hydrocarbons:

- Excavation and off-site disposal
- In situ soil venting
- In situ biodegradation
- Above-ground or in situ chemical oxidation

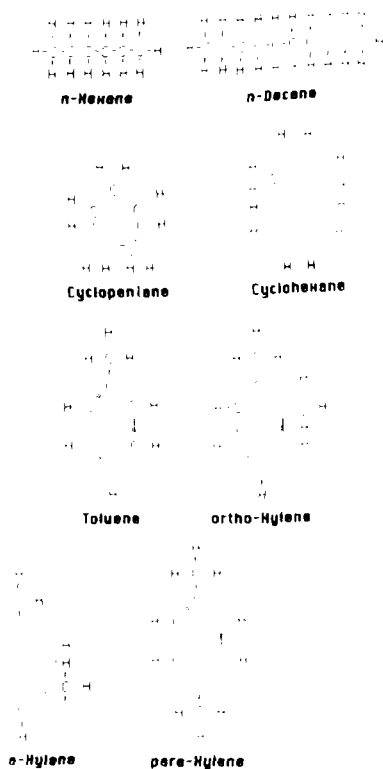
Excavation of site soils may be necessary if volatile compounds present. As shown in Figure 1, petroleum products with low boiling points will tend to be taken in areas critical in order not to release compounds. As shown in Table 1, benzene is the most significant compound in terms of volatility. It is expected to be one of the most volatile compounds in gasoline.

Next, let us consider in situ remediation of gasoline will have a major

TABLE 4
Physical/Chemical Properties of Selected Petroleum Hydrocarbons

Compound	Molecular Weight	Density	Solubility (@ 20 C)	Boiling Point, °C	Vapor Pressure @ 1 atm and (°C)
Pentane	72.15	0.626	360 (16)	36	430 (20)
Hexane	86.17	0.66	13 (20)	68.7	120 (20)
Decane	142.28	0.73	0.009 (20)	173	2.7 (20)
Cyclopropane	42.08	0.72	37000	33	760 (33)
Cyclopentane	70.14	0.751	<1000		200 (13.8)
Cyclohexane	84.16	0.779	55 (20)	81	77 (20)
Benzene	78.11	0.878	1780 (20)	80.1	76 (20)
Toluene	92.1	0.867	515 (20)	110.8	22 (20)
ortho-Xylene	106.17	0.88	175 (20)	144.4	5 (20)
meta-Xylene	106.17	0.86	175 (20)	139	6 (20)
para-Xylene	106.17	0.86	198 (25)	138.4	6.5 (20)

Compiled from various sources



Chemical structures of selected petroleum hydrocarbons.

of the contaminants. We know that the possible phases in which petroleum can be found. Hydrocarbons are usually in the unsaturated soils. Next, the hydrocarbons in the vadose zone can also volatilize and contribute to the soil gases. We can expect to find spilled petroleum in the soils, the aquifer, and in the soil

Physical Properties of Petroleum Hydrocarbons

Boiling Point, °C	Vapor Pressure @ 1 atm and (°C)
36	430 (20)
68.7	120 (20)
173	2.7 (20)
33	760 (33)
	200 (13.8)
81	77 (20)
80.1	76 (20)
110.8	22 (20)
144.4	5 (20)
139	6 (20)
138.4	6.5 (20)

gases.

Once petroleum hydrocarbons are introduced into the environment they interact with the surrounding soils. Some of the major processes affecting these chemicals include adsorption, chemical degradation, diffusion, volatilization, and biodegradation. As we have seen, many constituents of petroleum products (such as the alkanes and aromatics) are non-polar compounds and have only limited solubility in water. Naturally occurring soil compounds, such as humic and fulvic acids, may dissolve in water and help to dissolve other non-polar compounds. Covalent bonding of contaminants to the functional groups of humic molecules can also serve to immobilize contaminants. In addition, clays in the subsurface frequently have positively charged surfaces that can bind polar as well as charged contaminant molecules.

A common way to compare specific compound migration potentials is to use K_{oc} values. K_{oc} is a measurement of the tendency of an organic compound to be adsorbed by the soil. The higher the K_{oc} value for a compound, the lower its mobility and the higher its adsorption potential (U.S. Environmental Protection Agency 1988). Table 5 gives K_{oc} values for some of the compounds found in gasoline. A more complete description of contaminant-soil interactions is beyond the scope of this article. Interested readers can consult soil chemistry texts such as the volume by Dragun (Dragun 1988).

The problem with remediating a gasoline spill is that we do not find all of the chemical constituents of "gasoline" in each of the three different phases previously described. The compounds that make up gasoline and have low solubility, low volatility, and strong adsorption characteristics will be most prevalent with the site soils. The compounds with high solubility will be most prevalent in the aquifer, and the compounds with high volatility will be most prevalent in the soil gases. We tend to have a natural separation of the chemical components of any petroleum product.

Specific chemical properties affect the technologies that are used for remediation as well as the methods used for analysis. We will first review their effects on site remediation.

Soils Remediation

There are four major ways to remediate soils contaminated with petroleum hydrocarbons:

- Excavation and off-site disposal
- In situ soil venting
- In situ biodegradation
- Above-ground or in situ chemical oxidation.

Excavation of site soils may result in the loss of the volatile compounds present. As dirt is exposed to the atmosphere, petroleum products with high vapor pressures and low boiling points will tend to volatilize. Some care will have to be taken in areas where air emissions are critical in order not to release large amounts of these compounds. As shown in Table 4, benzene (the most significant compound in terms of human health effects) is expected to be one of the most volatilized compounds.

Next, let us consider in situ soil venting. The components of gasoline will have a major effect on the suitability

TABLE 5
Adsorption Coefficients for
Selected Gasoline Compounds

Chemical	K_{oc} Value
n-Pentane	568
n-Hexane	1097
n-Heptane	2361
Benzene	50
Toluene	339
ortho-Xylene	255

Adapted from U.S. EPA 1988

of this technology. The basis of soil venting is to move air past the contaminated soils and to transfer the organics from a liquid phase into the vapor phase. This mass transfer process effectively removes them from the soil. The rate that the hydrocarbons will vaporize is related to the vapor pressure and the boiling points of the specific compounds. Using the property values listed in Table 4, not all of the gasoline constituents are expected to be amenable to this treatment. Even fewer components of diesel and fuel oil are amenable to soil venting technologies.

Soils can be cleaned by biological methods. All of the compounds found in gasoline, diesel, and fuel oil are degradable by bacteria. However, enhanced bioremediation frequently requires improvements in the subsurface growth environment surrounding the indigenous microorganisms. The site hydrogeologist must help to ensure the transfer and mixing of oxygen and nutrients throughout the contaminated zone. The hydrogeologist must also take care to ensure that soluble and/or volatile components are not further spread through the action of any liquids introduced at the site.

Lastly, chemical oxidation can also be used to remediate hydrocarbon-contaminated soils. This commonly relies on the use of hydrogen peroxide and catalysts to destroy the hydrocarbons present. The treatment process may have to be repeated until all of the regulated hydrocarbon constituents reach acceptable concentrations.

Aquifer Remediation

There are two major strategies employed to remove petroleum hydrocarbons from contaminated aquifers: pump and treat in above-ground systems and in situ bioremediation. The properties of the specific organics present will have a significant effect on pump-and-treat methods. Free product floating on the aquifer can be removed through induced ground water level depression and mechanical pumping. Compounds that are soluble in water can be removed from the subsurface and treated above ground with a variety of technologies. Extremely hydrophobic chemicals may remain adsorbed to subsurface soil particles and escape remediation using pump-and-treat methods.

In situ biodegradation is frequently an effective remediation strategy because all of the compounds are biodegradable. Again, care must be taken to ensure that

soluble contaminants are not further mobilized by the subsurface introduction of any liquids.

Analyzing for Petroleum Hydrocarbons

Finally, the variable composition of petroleum products can have a major effect on their identification and quantitation. Chemical analysis for petroleum hydrocarbons is used throughout the site remediation process for several purposes, including:

- Initially, to identify and quantitate the chemicals present
- During the project, to monitor the progress of the remediation effort
- Lastly, to certify that the cleanup effort is complete.

Because petroleum products are complex mixtures of chemicals, special problems are faced in analyzing for these compounds. Data interpretation also becomes much more complex. We will point out some of the difficulties of analyzing water and soils for hydrocarbons, as well as some common pitfalls in interpreting this data.

In general, water samples are easier to analyze than soil samples. This is because water samples are more homogeneous than soils samples (assuming no free product is present). Soils tend to be much more heterogeneous in nature, and their actual inorganic and organic composition may change widely over small horizontal or vertical distances. Homogeneity is desired from an analytical standpoint because the sample may be more representative of the site conditions at a given point and time. Heterogeneous samples are more likely to contain organic "hot spots," regions of contamination much higher than typically found.

There are two major types of analyses that can be performed with water or soil samples containing petroleum products. The first type of method is non-specific and attempts to quantitate the total mass of hydrocarbons present. This method is usually a variation of the "oil and grease" analysis originally performed with waste water. With this method, a given volume of water or wet weight soil sample is extracted with a solvent such as fluorocarbon-113. The total mass of hydrocarbons dissolved in the solvent is then quantitated by comparing the infrared absorption of the extraction liquid against that of a defined hydrocarbon mixture.

The infrared spectrophotometric method previously described, EPA Method 418.1: Petroleum Hydrocarbons, Total Recoverable (U.S. Environmental Protection Agency 1983), has two major drawbacks when used to analyze complex petroleum products. These drawbacks are:

- Volatile compounds are usually lost in the extraction procedure. This applies particularly to the analysis of gasoline contaminated materials.
- Samples are quantitated against a known hydrocarbon mixture (for instance, a mixture of isooctane, n-hexadecane, and chlorobenzene), not the specific petroleum product spilled at the site. All hydrocarbons do not respond equally to infrared analysis, and comparison of the unknown to the standard mixture may result in artificially high or low hydrocarbon concentrations.

Anyone interpreting results from such a test must also consider that:

- All materials (contaminants or benign materials) that are soluble in the solvent will be extracted. These materials may create positive or negative interferences with the hydrocarbon quantitation.
- Soils samples must also be analyzed for moisture content in order to correct the hydrocarbon concentration for the weight of the water present. Remember that a certain wet weight of soil is initially used for extraction. Failure to correct for the percentage of moisture content of the soils results in artificially low hydrocarbon concentration values.
- All extraction and quantitation procedures have a degree of variability. For this method, variability may be 25 percent or greater depending upon the specific hydrocarbons present and the soil matrix involved. Specific soil spikes may be used to gain a better understanding of the site-specific variability of this technique. The laboratory QA/QC data should be carefully evaluated in interpreting final hydrocarbon concentration values.

The extraction-IR quantitation method does have certain advantages. It is relatively quick and easy to perform and is not very expensive (typically \$50 to \$75). This technique is perhaps most valuable for use as a screening step in determining the presence of hydrocarbon contamination. It cannot identify and quantitate the specific compounds present, and we do not recommend its use in setting cleanup standards or for certifying that a remediation is complete.

The second method for analyzing hydrocarbons in water and soils involves the specific quantitation of organics with gas chromatography-mass spectrometry (GC/MS). EPA Method SW846-8240 describes a GC/MS purge and trap technique for quantitating volatiles present in a sample. Volatile compounds present in a liquid sample are purged using an inert gas and captured on an adsorbent trap. The captured organics are then eluted from the trap into the GC for analysis. Soil samples are rapidly heated and the volatile compounds likewise captured on a trap for further analysis (U.S. Environmental Protection Agency 1986).

EPA Method SW846-8270 describes a GC/MS methylene chloride extraction method for quantitating semivolatiles present in a sample. Soil and liquid samples are extracted in an analogous manner. Unfortunately, a single method is not readily available for identifying and quantitating both volatiles and semivolatiles present in a water or soil sample (U.S. Environmental Protection Agency 1986). To completely characterize a water or soil sample, both the volatile and semivolatile GC/MS analyses should be completed.

GC/MS methods offer the ability to both identify and quantitate the specific organics present. This may be critical if the remediation effort is driven by the desire to reduce only certain compounds, such as benzene, toluene, or xylene. The benefits of GC/MS work have to be weighed against their higher costs. Prices of \$100 to \$300 per sample are not unusual for either of the volatile or

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semivolatile GC/MS tests described.

Gas chromatography can also help determine whether a fuel oil sample has been biologically weathered. This is done by comparing the ratio of certain straight chain alkanes ($n\text{-C}_{17}$ and $n\text{-C}_{18}$) with specific branched chain alkanes (pristane and phytane, respectively). The branched chain alkanes are more resistant to biodegradation, and biologically weathered samples typically have low straight chain to branched chain ratios. A more complete description and application of the "pristane/phytane" test is found in the paper by Senn and Johnson (1985).

In general, great care must be taken in deciding which analytical methods are used for identifying and quantitating petroleum hydrocarbons present in soils and liquids. Equally important is the careful evaluation of data generated by these tests. Just because a number is presented in an official looking report does not mean that it is correct or even representative of the overall conditions at your site.

Summary

As the reader can see, the properties of specific organic chemicals present in a complex petroleum product have a major effect on the distribution of the compounds in a soil/gas/liquid matrix. The initial mixture of compounds will tend to separate and equilibrate in the soil and aquifer environments. The volatile compounds will tend to be found in the soil gases and the atmosphere. The non-soluble compounds will tend to stay with the soil particles, and the soluble compounds will tend to dissolve and travel with the water moving through the contaminated area. However, many complex reactions can take place between contaminants and the subsurface environment to affect these generalizations.

The identification and quantitation of petroleum products in soils and ground waters is a complex and difficult task. General procedures measuring the total mass of extractable hydrocarbons can provide useful site information, but the limitations of these tests must be considered when evaluating the resultant analytical data. Gas chromatography with mass spectroscopy provides a more definitive method of identifying and quantitating hydrocarbons present in soil and liquid samples. However, the advantages of using these methods are frequently (and in many cases short-sightedly) overcome by their higher costs.

Lastly, we would like to make one other observation based upon the data provided in this article. Because the individual hydrocarbon contaminants partition unevenly between site soils, waters, and gases, a single type of remediation technology may not be able to efficiently and cost-effectively remove all of the components present at a site. Currently available remediation technologies (such as soil excavation, soil venting, pump-and-treat, in situ bioremediation, etc.) tend to work best only against certain specific compounds. There is no single remedial method that is best for all classes of compounds under all types of site conditions. Successful remediation efforts may have to rely on the proper application of a combination of remediation technologies.

References

- Dragun, J. 1988. *The Soil Chemistry of Hazardous Materials*. Hazardous Materials Control Research Institute, Silver Spring, Maryland.
- Hawley, G. 1981. *The Condensed Chemical Dictionary*. Tenth Edition. Van Nostrand Reinhold Co. Inc., New York.
- Morrison, R.T. and R. N. Boyd. 1973. *Organic Chemistry*. Third Edition. Allyn and Bacon Inc., Boston, Massachusetts.
- Perry, J.J. 1984. Microbial metabolism of cyclic alkanes. *Petroleum Microbiology*, Ed. Ronald M. Atlas. Macmillan Publishing Co., New York, New York. pp. 61-98.
- Senn, R.B. and M. S. Johnson. 1985. Interpretation of gas chromatography data in subsurface hydrocarbon investigations. In *Proceedings of the NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water—Prevention, Detection and Restoration*. Houston, Texas, November 13-15, 1985. National Water Well Association, Dublin, Ohio.
- United States Environmental Protection Agency. 1988. *Cleanup of Releases from Petroleum USTs: Selected Technologies*. EPA-530/UST-88/001.
- United States Environmental Protection Agency. 1986. *Test Methods for Evaluating Solid Waste*. Volume 1B. Third Edition. SW846.
- United States Environmental Protection Agency. 1983. *Methods for Chemical Analysis of Water and Wastes*. EPA-600/4-79-020.

Biographical Sketches

Evan K. Nyer is a private consultant specializing in process design for ground water treatment systems. His book Groundwater Treatment Technology was published in 1986. He is actively involved in the design and construction of treatment systems for contaminated ground water and teaches courses on treatment technology for NWWA, U.S. EPA, several universities, and private companies.

George J. Skladany is the manager of operations for Detox Inc. in Dayton, Ohio, where his responsibilities include the design of laboratory treatability studies. He teaches courses in site remediation for the U.S. EPA, the UCLA Extension Program in Toxic and Hazardous Materials Control and Management, and private companies. Skladany received a B.S. in cellular and molecular biology from Carnegie-Mellon University in 1978 and an M.S. in environmental systems engineering from Clemson University in 1984.

Ground Water Treatment Reviews

To have your contaminated ground water reviewed please include the following information:

- List of contaminants to be removed
- Concentration of contaminants.
- Flow to above-ground treatment system.
- Quantity of contaminants.
- Effluent requirements.
- Regulations controlling the installation.

Send all request to Treatment Technology, c/o Ground Water Monitoring Review, 6375 Riverside Dr., Dublin,

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